Isotope Applications to Groundwater Management

Objective

To develop a sound technical basis for development of groundwater resources in the Tabor and Opechee basins to support the construction of rural water supply systems while preventing over-exploitation or pollution of the resources.

Background

Clean and reliable water supplies are a high priority for national development in Markos. Past development efforts have focused on large-scale surface water projects for irrigation and hydro-power. The focus of current development efforts has shifted to decentralized rural water supplies that can better serve household needs and small-scale agriculture or ranching. Groundwater is the primary resource to be exploited in these development efforts. In the semi-arid regions of Markos it is more widely available and dependable than surface water and requires less infrastructure for treatment. IAEA cooperation is sought to help implement the technical studies necessary to support rational development and management of the available resources.

Institutional and Organizational Factors

Recent changes in water rights law and national water management organizations have resulted in increased attention to groundwater resources. Previously, groundwater usage was not regulated under permits from national authorities. Water laws enacted over the last five years have given national institutions the authority to regulate groundwater, as well as surface water, under a system of basin-wide management plans and permits for individual well owners. The Ministry of Water and Natural Resources has the primary regulatory authority under law, but depends on groundwater experts in the national Geological Survey to provide the basic information on the quality and capacity of the aquifers that it needs to develop water management plans.

Water management planning remains in the early stages, and the detailed technical and legal framework for water development is still being worked out. Two relatively small basins have been selected as pilot areas and detailed hydrogeological and hydrological studies are being conducted. Results from these two areas will help define the process to be applied to other basins throughout the nation.

Other Donor Involvement

International groups, including UNICEF and UNDP, in conjunction with several bilateral organizations and NGOs, have sponsored a variety of rural water supply and sanitation projects, watershed management projects, and small-scale irrigation projects. These projects have achieved limited impact in the local areas served and have helped raise awareness concerning water issues, but are generally poorly coordinated with each other and have had little impact at the national level.

Restructuring of the national government under the terms of International Development Bank loans has contributed to the water rights reforms discussed above. However, the restructuring has also reduced the ability of the national organizations to implement their new regulatory authority, as cuts in budget and personnel have severely limited their capacity to develop new programs. Once resource assessments are completed and permits are in place, a system of user fees is planned to finance the regulatory system. The Bank is currently financing a hydrogeological assessment of one aquifer targeted for supplemental water supply for the capital city, however additional resources are needed to address other regions of the country, including the two basins selected for pilot-scale assessments.

Previous Bank projects involved large water, power, and irrigation facilities on major rivers. There are limited opportunities for further projects of this type, especially in semi-arid regions of the country.

On-Going Program Activities

Pilot-scale studies in the Opechee and Tabor basins are underway. The present program includes geophysics and mapping, well drilling, aquifer tests, water level surveys, and basic chemical measurements of water quality. These investigations yield information on the extent of the aquifers, the quality of the water they contain, and the rate at which it can be pumped from a given borehole.

However, important information on the locations and rates of recharge, mixing between surficial and deeper aquifers, and other dynamic processes cannot be easily determined using the available techniques. These dynamic factors are the primary focus of regulatory efforts. The Geological Survey of Markos seeks technical cooperation assistance from the International Atomic Energy Agency to demonstrate isotope techniques for groundwater assessment and train personnel in their application. These activities will complement on-going work in support of the national water management planning initiative.

Technical Basis for Isotope Application

Environmental isotopes provide a unique tool for assessing the large-scale dynamics of aquifers, including definition of recharge rates and locations. This information is important in determining the sustainable yield of an aquifer and in protecting recharge zones from pollution. The decay of atmospheric tritium and C-14 in groundwater allows the “age” of groundwater, or the mean travel time between recharge areas and production wells, to be calculated. C-14 analysis also requires C-13 analysis to evaluate the effects of chemical reaction with aquifer materials. Together with conventional hydrogeological data, the mean travel time can be used to estimate the overall rate of recharge to an aquifer. This recharge rate defines the sustainable yield of the aquifer, or the maximum amount of pumping that can be allowed without depleting the aquifer.

The deuterium and oxygen-18 content of water varies with altitude, geographic location, and evaporation. These variations in stable isotope content can be used with conventional data, and tritium and C-14 results, to define recharge and discharge areas, trace mixing patterns, and evaluate the importance of evaporation in the chemical balance of the aquifer. These data are important in understanding controls on water quality and in regulating activities that may pollute groundwater resources.

Locally, the Opechee and Tabor basins consist of graben blocks between hills rising up to 1000 meters above the basin floor. Recharge is presumed to occur via runoff from the hills infiltrating alluvial fans along the basin margins. The geology of the basins consists of variably thick alluvial deposits overlying a Cretaceous formation of interbedded sandstones and shales. Locally, basalt dikes are also present. Crystalline basement is exposed on the hills but is deeply buried in the basins. Shallow groundwater is frequently saline, although fresh-water zones are present, presumably near the most active recharge areas. Deeper groundwater has not been exploited to date, but is a target of the current exploration campaign.

Previous IAEA projects in Markos have provided basic training in isotope techniques for scientists with the Geological Survey and have collected background data on local isotope systematics that are needed for the applied studies proposed here.

Scope of Activities for the Proposed Project

A total of ten exploration/production wells are being drilled in each basin as part of the pilot assessments. Water level measurements and aquifer test data on these wells will be available by mid 2000. These wells will also be sampled for basic chemical parameters. Analysis of tritium, C-13/14, deuterium and O-18 will be coordinated with chemical analyses to provide a complete data set for interpretation. In addition to the twenty new drilled wells, numerous shallow dug wells are located throughout the study areas. A survey will be made of these wells and suitable locations will be included in the isotope assessment to improve its geographic coverage. Multiple sampling campaigns may be necessary if initial results suggest strong seasonal influences or rapid dynamics.

The proposed isotope activities depend on support from the IAEA in the form of analytical services or equipment and training to allow local analysis. For the 2000 sampling, it will be impractical to analyze samples locally, but a national capacity for isotope analysis will be important as the water resource assessment process moves to a national scale in subsequent years. A liquid scintillation counter for tritium and C-14 and training in analytical techniques are therefore requested from the IAEA. Stable isotope analyses are planned at a regional facility or in Vienna.

Expert assistance will be needed to refine the scope of activities and develop a detailed project workplan. Additional expert assistance will be needed to help local personnel interpret isotope results and apply them

to groundwater models being developed as resource management tools. Fellowships are also sought for more in-depth training for project personnel.

Improved field equipment is also needed to ensure that representative samples are collected. Electric submersible pumps, water quality meters, and field chemical analytical supplies are requested. A dual-station differential GPS system will also be needed to obtain survey data for village wells and create accurate water level maps. While these items are not directly related to the isotope measurements, isotope data are meaningless without proper field procedures and supporting chemical data.

Expected Results

The results of the proposed isotope study will help estimate recharge rates, locate areas of active recharge, and define well-head protection zones around production wells. In a more general way, the data will improve the understanding of relations between shallow and deep aquifers and the roles of mixing and evaporation in determining water quality. These results will be summarized in a report, including all appropriate maps and cross sections, integrating the complete findings of the pilot assessments in the Opechee and Tabor basins.

Follow-up and Application to Development Objectives

Information on groundwater resources developed under this project will be reported to the Ministry of Water and Natural Resources, together with other results from the ongoing pilot-level basin assessments. The information from these pilot assessments will serve as the technical basis for permits allocating water rights and for planning future water development in the basins. Only by developing technically defensible resource assessments and can fair and equitable management plans be implemented.

The process demonstrated in these two basins will serve as a model for water resource assessments nationwide over the next ten years. It is important to demonstrate the role of isotopes in these initial assessments so that an isotope component will be included in all subsequent basin assessment and planning activities. A national groundwater monitoring network is being established under the Geological Survey, and will be responsible for providing technical data needed to assess the performance of basin-level management plans and review permits.